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DEEP AND SHALLOW FERTILIZER PLACEMENT*

The work that has been done in the United States on the localized application of fertilizers has had the consequence that placement has come to be almost synonymous with the application of fertilizers in bands (or sometimes a single band) usually in such a position that the band of fertilizer lies to the side of and a little below the row of seeds. This is known as row-placement—the bands being assumed to be continuous. The bands are usually but not always of constant depth. Obvious modifications of continuous row-placement are "hill" placement and other forms of interrupted bands; and sowing the seeds together with the fertilizer, either down the same drill-spout or in such a way that the fertilizer falls in the same row as the seed, but at a little distance from the last-sown seed.

The practice of sowing seed and fertilizer from one machine is traditional and has been little investigated by science workers. Placement of fertilizers in a row or rows distinct from the seed-row is a comparatively modern idea, though older than many people think. It has attracted much attention in recent years through the publicity given to trials of row-placement in America, and considerable hopes have been built upon the performance expected from it: *e.g.*, the higher yields alleged to result from row-placement of a given quantity of fertilizer instead of broadcasting the same amount have led to expectations of generally increased yields or alternatively of sustained yields from use of a smaller quantity of artificials.

It has been widely overlooked that many of these attributions of improvement from row-placement are misplaced, since too often the only control treatment has been "no fertilizer". In the absence of a control treatment with broadcast application, the real comparison is not placement *versus* broadcast, but fertilizer *versus* no fertilizer—the effects of placement being confused with those of fertilizer. Secondly, the publicity given to row-placement must have led many people to think that row-placement of bands of fertilizer to field crops is standard practice in parts of the U.S.A.; whereas the truth seems to be that most of the placement applications have been made either by hand or with single special-designed machines constructed to the order of an experimental station; and some workers in the field

* Reproduced from *Soils and Fertilizers*, Vol. VIII, No. 2, 1945, pp. 67-69.

of placement state specifically that their experimental suggestions cannot be generally adopted owing to the lack of commercial machines capable of performing simple row-placement in the manner indicated. One of a few crops for which side-placement of fertilizer in bands is standard practice is lettuce grown on irrigated ridges in Arizona, but the conditions constitute a special case.

So far as can be judged, the possibility of getting an increase of yield from ordinary row-placement of fertilizer in shallow bands to common unirrigated annual crops is about equal to the possibility of damage being caused to the crop; in both cases in comparison with what happens when the same amount of fertilizer is broadcast. The same is broadly true of the sowing of seed and fertilizer together, except that rule-of-thumb practice has indicated that in some regions the probability of benefit is great enough to justify the occasional risk.

It seems that the probability of harm or benefit resulting from any shallow localized (as distinct from broadcast) application of fertilizer is bound up with both the texture of the soil and the weather. The effects of weather chiefly result from precipitation and temperature in so far as these affect the moistness of the top soil. Texture and structure decide the amount of water that can be retained by the soil. The sum of these factors, together with the amount and chemical nature of fertilizer applied, decides the osmotic pressure or "salt effect" exerted by the fertilizer. A locally-concentrated application of fertilizer will produce a high osmotic pressure if the soil moisture is for any reason low; hence in a dry season, and in sandy soil, localized placement is likely to bring about poor germination and to affect the later growth of plants through what is called "burning"; this last being probably brought about by an excessive concentration of salts acting injuriously upon roots.

The principal ideas underlying the attempts to introduce (shallow) placement seem to have been to minimize loss of fertilizer by leaching and fixation through avoidable exposure of the fertilizer to the action of water and soil respectively, and to make it easy for the plant roots to take up nutrient elements quickly. It is difficult to say how far the first idea has been justified. On the other hand, recommendations to place a moderately high concentration of fertilizer in particular regions of the topsoil for the purpose of aiding and as it were encouraging the plant roots to absorb have not been uniformly justified—possibly for the reason that investigation of osmotic effects produced by fertilizer added to soil came much later than the majority of the somewhat empirical attempts at finding workable methods of placement. It looks as if anyone going to adopt any form of localized shallow placement as standard practice must either guarantee the weather or find some other method of standardizing the moisture content of his soil and the osmotic pressure of the soil solution. In this latter connexion the method of overhead irrigation with very dilute nutrient solutions is of interest.

A method of localized application that seems to be free of the gross defects of row-placement in the topsoil is the general method of applying the fertilizer fairly deep—at about plough-sole depth—either by actual ploughing-down or by use of an implement which places the fertilizer on or near the furrow bottom. Shallow subsoiling may be used in conjunction so as to scatter the fertilizer through part of the upper subsoil or the lower layers of the topsoil if that is deep. The method is essentially row-placement, but the formation of neat bands of fertilizer is not aimed at and chance distribution is allowed to act to a more or less limited extent. By these means the fertilizer is put mainly in the future root zone, but it seldom occurs in concentrations which would be injurious if the soil should partially dry out; and the greater depth as compared with the customary modes of shallow placement makes it still less likely that the moisture content of the soil will fall low enough to bring about injury. The method has the additional advantage that it can be used with ordinary equipment. It is claimed to have produced remarkable results when not only fertilizer, but also limestone was ploughed down. The probability of increased benefit from liming by this method will be readily conceded, since although there is no mechanical reason why ground limestone should not be deposited in shallow bands, the effects of such narrow bands of limestone are likely to be sharply restricted during the season of their application at least.

Beard (1) of Ohio states that under such conditions as exist in the United States Corn Belt no other method of applying 500 to 1000 lb. of 8-8-8 or similar fertilizer per acre has proved as satisfactory under a variety of conditions for maize and some other row crops as has ploughing down. He gives the results of experiments somewhat vitiated by unfortunate weather. The available results apply only to the better soils but it appears that ploughing-down 800 lb. of fertilizer of about 10-10-10 composition appreciably increased yields of hybrid maize over the yields obtained after the ordinary method of application. It will be noted that these rates of fertilizer are somewhat high and are therefore likely to conduce to "burning" under unfavourable conditions. In these experiments all the fertilizer ploughed-under was applied with a grain drill before ploughing.

Possibly more striking testimony comes from Tiedjens of New Jersey (2). He states: "In 1940 not more than one per cent. of the tomato growers in New Jersey plowed under all their fertilizer despite the fact that the Department of Vegetable Gardening had recommended the practice since 1936. Since 1941 the number of

(1) D. F. Beard. *Better Crops with Plant Food* 28, No. 10, 1944 (15-18, 42-44).

(2) V. A. Tiedjens. *Ibid*, 29, No. 1, 1945 (23-26, 43-44).

growers following the practice has rapidly increased, so that by 1944 approximately 50 per cent. of the growers are plowing under all or part of their fertilizer. Along with this, liming materials in greater amounts are being plowed under." Exceptionally good response to superphosphate was got by placing it as deep as four to six inches below the ploughed layer, and this placement also improved root distribution. A wide root distribution minimizes losses of nutrients by leaching, which may consequently be less with a deep placement than with a shallow row-placement. What is especially needed to develop deep placement is a machine that will give something approaching a "broadcast" distribution of the fertilizer in the subsoil. Deep placement, like other types of placement, affects and economizes phosphorus rather than potash or nitrogen, and one result of a general adoption of fertilizer placement might be a marked fall in the proportions of phosphate included in standard fertilizer mixtures.

A trial in Brazil with onions cultivated and manured to depths between 15 and 45cm., on two soils (3) showed only small effect of depth of either cultivation or manuring on a good soil; yields without fertilizer fell off with increasing depth of cultivation on a poor soil (no doubt owing to admixture of subsoil with topsoil), the yields with fertilizer being roughly constant at all depths of application but much less than any yield on the good soil.

(3) A. T. Prado. *Bragantia* 3, 1943 (333-346).

MISCELLANEOUS NOTES

A New Agricultural Weed-Killer

An entirely new and revolutionary type of selective weed-killer for agriculture has been discovered by Imperial Chemical Industries. After exhaustive tests lasting two years, trials have now been put on a nation-wide basis by I.C.I. and by the Ministry of Agriculture through the Country War Executive Committees. The weed-killer which is known as methoxone is a growth substance of the plant hormone type. It was in 1940 that I.C.I. discovered that two chemicals of this type showed remarkable properties as selective weed-killers. Their peculiarity was that they would kill charlock and many other weeds without harming cereal crops. This justified further research into the plant hormone type of substances, and in 1941 it was found that all had properties as selective weed-killers, some of them being extremely active.

In 1942 one of them, methoxone, was selected as likely to be the most useful for agricultural purposes. In 1942, other scientists in Great Britain also began investigations on a parallel substance, chloroxone, the name given in Britain to the weed-killer recently announced by the Americans and called by them D. C. P. (It may be noted that the first experiments with chloroxone as a weed-killer began in the U.S.A. in July, 1944.) Field experiments on a large scale with methoxone and chloroxone were carried out during 1943 and 1944 by I.C.I. and the Agricultural Research Council working together. As a result of these trials methoxone proved itself the more effective of the two. The selective properties of methoxone lie in its power to kill certain types of weeds while leaving cereal crops and grasses unharmed. The trials already carried out have shown that when it is applied at a rate of 1 lb. per acre, weeds such as yellow charlock, wild radish, corn buttercup, and penny-cross growing in corn are killed, but the crop is unharmed. The most important factor arising from this revolutionary discovery is that weeds can be eliminated in the early stages of growth before they have been given a chance to rob the crop of the food available in the soil. Large increases in yields of wheat, barley, and oats should result. In grassland buttercup has been completely eliminated, this making available increased food for cattle. The programme of methoxone trials for this season is the most extensive ever carried out in Britain and is designed to obtain information upon a wide range of weeds under a variety of conditions.—(*Chemistry and Industry*, No. 14, pp. 109-10, 1945.)

* * *

Vitamin Content of Coconut Milk

In a letter to *Nature*, Vol. 156, No. 3954, pp. 175-176, J. M. Vandenbelt of the Research Laboratories of Messrs. Parke, Davis and Co., Detroit, Michigan, U.S.A., writes as follows: In 1941, while working with the microbiological assay of vitamins, stories of seamen and aviators stranded on 'coco-nut isles' became common, and it occurred to us to measure the vitamin content of the 'coco-nut milk' popularly supposed to be the dietary mainstay under such conditions. The values listed are those obtained for the centre fluid of an apparently normal specimen obtained at a local grocery store.

Nicotinic acid	....0.64	micrograms/c.c.
Pantothenic acid	....0.52	,,
Biotin	....0.02	,,
Riboflavin	<0.01	,,
'Folic acid'	0.003	,,

The concentration of two other vitamins for which microbiological assays were not available, thiamin and pyridoxine, were so low as to be negative toward colour tests, even though the material was first concentrated to some extent by adsorption and elution.

It is evident that the juice was not of high nutritive quality. The minimum daily requirement of riboflavin, for example, according to the Food and Nutrition Board of the U.S. National Research Council, for a 'very active' individual of 70 kilos is 3.3 mgm. per day. To meet this requirement, the daily consumption of coco-nut juice would have to be at least 330 litres.

(III) GILBERT AND ELLICE ISLANDS

BY

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History.—The Gilbert and Ellice Islands were visited only infrequently by Europeans until the 19th century when thousands of Ellice Islanders and a smaller number of Gilbertese were carried off to the plantations of Guatemala and Mexico. The islands were under no special jurisdiction until 1892 when Great Britain proclaimed a Protectorate over each Group.

The islands were annexed to the British Empire in 1915 on the expressed desire of the native governments. The Phoenix Group had been annexed by Great Britain in 1890 and was made part of the Gilbert and Ellice Islands Colony in 1937. Canton and Enderbury Islands, two small uninhabited atolls in the Phoenix Group, hitherto of no importance to anyone, sprang suddenly into international prominence as potential sites for trans-Pacific air bases. Great Britain and the United States of America both laid claim to them, and in 1939, after considerable negotiation, set up a joint control 'without prejudice to their respective claims'.

Geography.—The Gilbert and Ellice Islands Colony consists of 37 islands lying between latitudes 4° 45′ north and 10° 45′ south, and longitudes 157° west and 169° 35′ east, thereby lying astride both the Equator and the international date line. The total land area of the Colony is less than 200 square miles but the various islands are so scattered that a rectangle of 1,000,000 square miles of ocean would not contain them all.

Ocean Island is geologically distinct from the rest of the islands, being an upheaved island of coral formation, rising to a height of 250 feet above sea level, which is rich in deposits of phosphate of lime. Phosphate of lime is mined by the British Phosphate Commissioners and constitutes the principal export of the Colony (*See* Tables 1 and 2). The other islands are all low, flat and sandy, nowhere rising to more than 15 feet above sea level. In most instances they are of true atoll formation consisting of mere ribbons of coral, some five to 50 miles long, often cut up into small islets separated by sandy channels fordable at low water, and surrounding lagoons. A few are reef-bound and without lagoons.

Production.—The soil is so sandy that it will support only a limited range of food products. Most of the islands are covered with coconut palms very closely but irregularly spaced. In the Gilbert and Ellice Groups all the coconut land is in the hands of the natives, but European plantations have been established on Fanning, Washington, and Christmas Islands. The coconut is used extensively for food and drink, and copra represents production in excess of native requirements. Some 5,000 to 7,000 tons of low grade copra are exported annually (*See Table* 2). Fish abounds and is one of the principal articles of diet. Apart from fish and coconuts, the natives subsist largely on the fruit of the pandanus palm (screw pine) and a coarse tuber known as babai (*Alocasia indica*). Babai is grown in pits which vary in depth, according to the water table, from two feet (*e.g.* Butaritari) to ten feet (*e.g.* Bariki in Tarawa). Breadfruit and paw-paw are grown in the villages. Native diet is deficient in variety but is of high nutritive value.

TABLE 1

Value of Imports and Exports

Year	Imports	Exports
	£*	£*
1918-19	92,351	139,183
1919-20	129,788	213,042
1920-21	212,406	342,599
1921-22	150,412	328,103
1922-23	137,128	291,086
1923-24	109,145	301,545
1924-25	137,695	369,576
1925-26	125,048	388,157
1926-27	113,453	395,728
1927-28	150,271	312,834
1928-29	190,436	348,272
1929-30	148,779	351,496
1930-31	194,425	253,344
1931-32	114,511	259,120
1932-33	117,920	398,068
1934-35	122,058	340,082
1935-36	133,865	366,887
1938-39	178,767	279,438

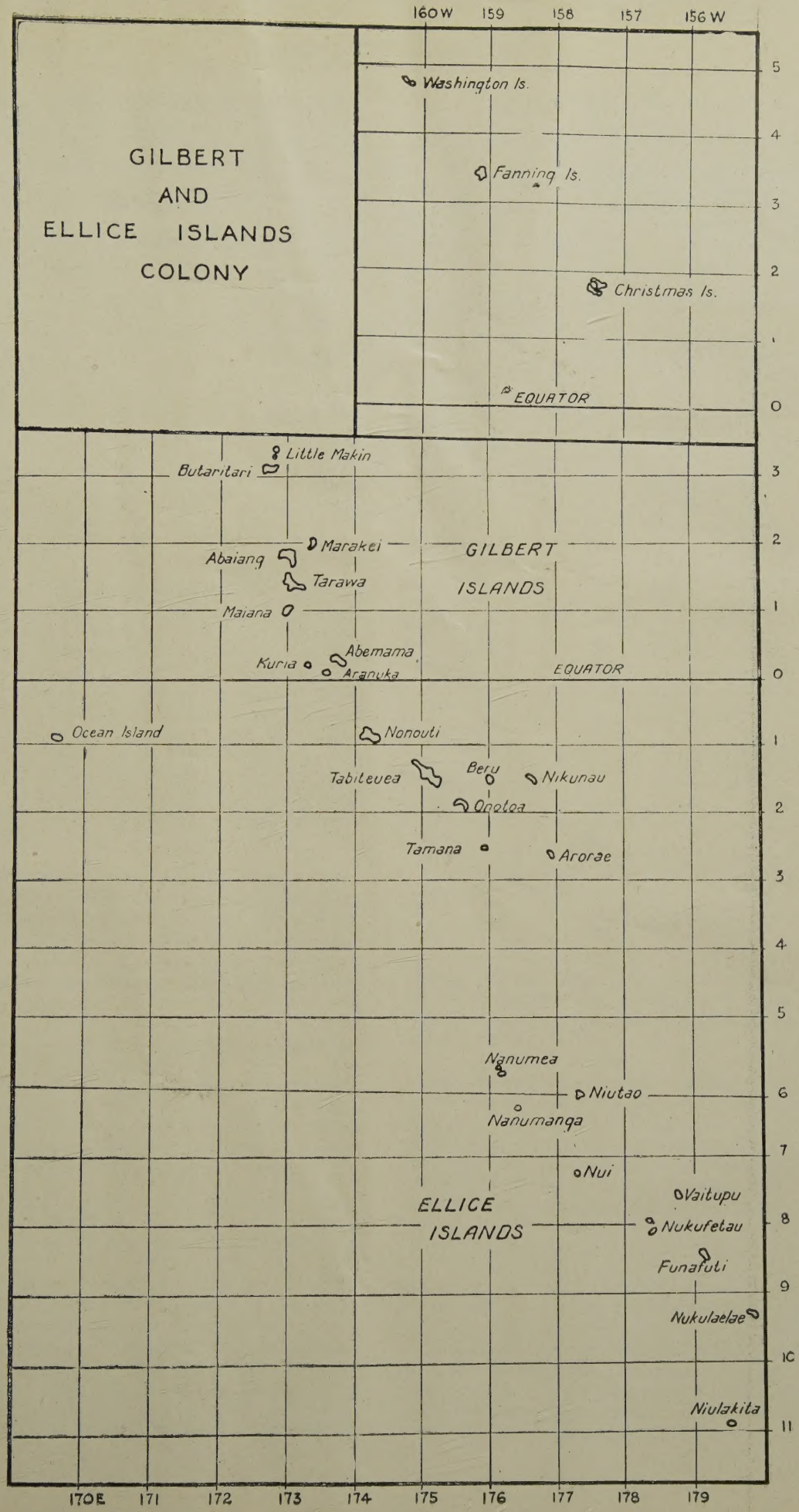
* Australian.

TABLE 2

Principal Exports

Year	Phosphate		Copra	
	Tons	£*	Tons	£*
1919-20 ...	105,838	158,757	3,431	54,010
1925-26 ...	188,335	258,960	12,410	250,176
1931-32 ...	142,200	191,970	6,715	67,150
1932-33 ...	224,200	302,670	8,995	94,842
1934-35 ...	234,400	281,280	7,153	58,148
1935-36 ...	324,250	316,144	5,368	50,617
1937-38 ...	329,800	296,820	4,850	54,307
1938-39 ...	297,888	208,521	8,861	70,717

* Australian.


GILBERT
AND
ELLICE ISLANDS
COLONY
160W
159
158
157
156W
Washington Is.
Fanning Is.
Christmas Is.
EQUATOR
Little Makin
Butaritari
Marakei
Abaiang
Tarawa
Maiana
GILBERT
ISLANDS
Abemama
Kuria
Aranuka
EQUATOR
Ocean Island
Nonouti
Tabiteuea
Beru
Nikunau
Onotoa
Tamana
Arorae
Nanumea
Niutao
Nanumanga
Nui
Vaitupu
ELLICE
ISLANDS
Nukufetau
Funafuti
Nukulaelae
Niulakita
170E
171
172
173
174
175
176
177
178
179

Imports.—(*Table* 3) A large proportion of the imports consists of explosives and machinery used in the mining of phosphate and of foods issued as rations to contract labourers.

TABLE 3

Principal Imports 1938-39

Commodity	Value £*
Explosives	23,953
Machinery	16,090
Coal	5,001
Meat	12,761
Fish	4,376
Rice	10,504
Biscuits	5,680
Fruits, etc.	7,717
Drapery	8,150

* Australian.

Labour.—The principal employers of labour are normally, the British Phosphate Commissioners and the firm of Fanning Island Plantations Ltd. The Commissioners employed about 500 natives and 800 Chinese mechanics and coolies under contract. About 100 natives of Ocean Island were employed as day labourers. The plantation Company employed about 130 Gilbertese, under contract, on their coconut plantations on the islands of Fanning and Washington. The great majority of the islanders never engage in wage earnings, but many of them are now serving in the Labour Corps.

Rainfall.—The annual rainfall ranges from 50 inches in the vicinity of the equator to 100 inches in the northern Gilberts and to 150 inches in the southern Ellice Islands. The islands with low rainfall are the least agriculturally favoured. September and October are the months with the lowest precipitation.

Population.—The total estimated population at the 31st December, 1936, was 34,000. The Gilbert and Central Pacific Islands are populated almost entirely by Micronesians, and the Ellice Islands (except Nui), by Polynesians. Ocean Island contains a number of Chinese recruited from Hong Kong for the phosphate mines.

The pressure of population on the land is greater in the Gilbert, than in the Ellice, Islands, and when the uninhabited Phoenix Islands were added to the Colony in 1937, the transfer of some 2,000 Gilbertese to Hull, Sydney and Gardner Islands was undertaken. In most of the Ellice Islands there still remains some spare coconut producing land. The people live in villages clustered on the main road which runs along the lagoon shore from end to end of nearly every island. The roads in islands occupied by Military Forces have been widened to take motor vehicles.

TABLE 4

Population

Islands	Estimated land area (Sq. miles)	Estimated Population at 31st December, 1936	
		Total	Per sq. mile
Ocean Island ...	2½	2,791	1,116
Gilbert Islands—			
Butaritati ...	10	1,648	164
Little Makin ...	4	754	188
Marakei	6	1,720	286
Abaiang ...	12	2,503	208
Tarawa	14	2,530	180
Maiana	10	1,491	149
Abemama ...	9	982	81
Kuria	4	253	63
Aranuka ...	5	291	58
Nonouti	12	2,260	188
Tabiteuea ...	19	4,045	213
Beru	11	2,511	228
Nikunau ...	7	1,857	265
Onotoa	8	1,687	169
Arorae	10	1,520	217
Tamana	2	1,027	513
Elice Islands—			
Nanumea ...	2	776	388
Nanumaga ...	1	545	545
Niutao	2	604	302
Nui	1	431	431
Vaitupu	5	687	135
Nukufetau ...	2	437	219
Funafuti ...	2	352	176
Nukulaelae ...	1	253	273
Niulakita	½	39	68
Central Pacific Islands—			
Fanning Island ...	15	175	12
Washington Island	6	131	—
Christmas Island	20	23	1.2
Total ...	203	34,323	

The houses are raised a foot or more from the ground on coconut logs, are usually thatched with pandanus and have moveable curtains of coconut leaf around the walls.

Land Tenure.—The native system of land tenure is described as a compromise between the communal and individual systems. In theory, a land owner has only a life interest in the property but in practice he is allowed to exercise reasonable initiative in the alienation of portions of his land to relatives outside the immediate circle of his next-of-kin. No sale of native lands to non-natives is permitted, and no lease may be granted for a longer period than 99 years, nor for any one parcel of land in any one island of greater extent than five acres, without the approval of the High Commissioner. The determination of ownership and the establishment of land registers has been in progress for many years. The purchase value of good coconut-bearing land in the Gilbert and Ellice Groups, as between native and native, has fixed itself by custom at £12 per acre.

Public Finance.—The revenue and expenditure of the Colony have each ranged from about £50,000 to £80,000 per annum during recent years. The main items of revenue in 1936/37 were: British Phosphate Commissioners, in commutation of certain taxation, £13,293; royalties at 6*d.* per ton on phosphate exported, £10,418; import duties, £15,376; export duty on copra, £3,871; Native Lands Tax (paid in copra) £5,415; and licences (principally stores and ships), £2,729.

Native Administration.—Much of the work of the Administration is done by the natives themselves. Each island which has an indigenous population has its own native Government, presided over by a Native Magistrate, whose duties include the administration of native laws and regulations and the supervision of the island's police, prisoners and prisons. Each village is in charge of one or more local headmen, according to its size and situation. Each island also has a Native Scribe, who collects licence fees, fines and tax-copra from the natives; keeps records of Government cash received and disbursed, births, marriages, deaths, rainfall, shipping; prepares minutes of Native Court Proceedings in prescribed books, and acts as the local postmaster. The native Government is under the general supervision of the European Administrative Officer of the district of which the island forms part.

Livestock. Pigs and poultry constitute the principal livestock and there are no horses, and, except on Niulakita, no cattle.

TABLE 5

Livestock

Nature of Livestock in Various Administrative Districts	Estimated Number
Swine—	
Ocean Island	150
Gilbert Islands	2,000
Ellice Islands	1,600
Fanning Island District... ...	20
Poultry—	
Ocean Island	800
Gilbert Islands	11,000
Ellice Islands	3,500
Fanning Island District... ...	650
Cattle—	
Niulakita	18

Population Problems.—The population problem in the Gilbert Islands may be expected to grow more acute from year to year. The population is said to have been kept in check by the widespread practice of abortion, and by a heavy death rate, particularly among infants. There is scope for further settlement in the Phoenix Group but the time is approaching when wider outlets will be required.

War Damage.—The Japanese occupied Ocean Island and several of the more northerly Gilbert Islands. All the islands except Ocean Island were afterwards recaptured by the United Nations. Several of the islands were the scene of bitter fighting, especially Betio in the Tarawa atoll which has been almost completely denuded of coconut palms. Large numbers of coconuts in other islands were cut down by the Japanese for the construction of fortifications. Other areas of coconuts and native food gardens, both in the Gilbert and Ellice Islands, have been cleared for the construction of air fields. Military camps have been established in several islands. Many of the menfolk are now serving in the Gilbert and Ellice Labour Corps. Some considerable time must elapse before the native food gardens are fully restored.

There appears little scope for the development of new export crops and the principal problem is to improve native food production. The possibility of developing an export trade in table and floor mats, fans, baskets and bags and panama hats is worthy of investigation. The mats and fans at present woven by native women from pandanus leaves are exceptionally good in design and finish.

RECENT SOIL WORK AT THE TAFO CACAO STATION

The Tafo soils not only satisfy Trinidad standards for cacao soils, but compare favourably with the best of the Gold Coast cacao soils. Tafo soils are light, having wilting co-efficents of 3-4 per cent.

Study of effects of overhead shading on soil moisture showed that a naturally shaded plot consistently contained a higher percentage of available moisture than the unshaded; the difference cannot wholly be ascribed to shade effect as the water table is higher on the shaded plot. In a trial of artificial shade on plots on the same soil type and at the same level above the water table, there was marked conservation of soil moisture in the shaded plots during dry periods. Available moisture was determined by subtracting wilting coefficient from total moisture.

To find whether forest trees had a beneficial effect by reducing soil moisture during rainy periods and conserving it during the dry seasons, a number of spot samples have been collected and the difference under and outside shade canopies measured relative to the standard error of sampling. No consistently significant results have been obtained.

Determinations of evaporation at top of canopy and well below canopy with and without natural or artificial shade showed that artificial shade reduced evaporation near the ground in the wet months to about the mean of evaporation in the forest-shaded and non-shaded plots, and in the dry season evaporation under artificial shade was close to that of the naturally shaded plot.—(*Soils and Fertilizers*, Vol. VII, No. 4, pp. 190-191)

OBSERVATIONS ON A TRIAL OF TREES AS SHADE FOR CACAO

BY

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Introduction

The two species of Erythrina referred to collectively as 'Immortelles', and specifically as 'Anauca' (*E. Poeppigiana* (Walp.) O. F. Cook) and 'Bocare' (*E. glauca* Willd.) are commonly employed as shade trees in Trinidad cacao plantations. These species are both susceptible to a disease which has destroyed many 'Bocare' trees in particular, during recent years. This disease of 'Immortelles' was studied by Baker (1) who suggested control methods and envisaged the possibility of finding another species of tree to replace the 'Immortelle', at least in certain districts. In the hope of discovering a suitable substitute, a trial of trees was started in 1940.

Objects

The primary objective of the trial was to find one or more tree species which would be unaffected by the fungus (*Calostilbe striispora* (Ell., & Ev.) Seaver) associated with the disease of 'Immortelle' trees. The secondary objective was to obtain general particulars of the trees, including growth rates, in order to facilitate the selection of one or more species which might combine resistance to disease with the special characteristics required of a cacao shade tree.

None of the trees in this experiment has yet shown symptoms of 'Immortelle' disease. This absence of disease when the 'Immortelle' trees are approximately five years old is not unexpected, because Baker (1) found that young 'Bocare' trees are generally resistant, whilst 'Anauca' trees are more difficult to infect than the 'Bocare'. The primary objective of the experiment has therefore not yet been achieved, because sufficient time has not elapsed for a comparison to be made of the tree species in this trial with respect to disease resistance. The secondary objective of the experiment has been partially attained, because it is considered reasonable to use growth measurements to-date, in order to differentiate between the tree species, with respect to adaptability for the conditions under which the 'Immortelle' disease occurs.

This experiment is described and the results to-date are recorded, because such preliminary observations seem likely to be useful, although the main purpose of the experiment will not be fulfilled until the merits of the trees as shade for cacao can be combined with observations on resistance to 'Immortelle' disease. Baker (1) found that 'Bocare' trees about 30 years old were readily attacked and he observed natural infection of a tree about 20 years old, but trees ten or twelve years old appeared to be immune. It is possible, therefore, that a comparison of the trees in this experiment as regards disease resistance may not be possible before 1960, when approximately 20 years will have elapsed from date of planting.

Methods

An area of cacao land near Sangre Grande was made available for the trial through the generous co-operation of Mr. A. Mendes. This area, which comprises parts of Sta. Carlotta and Grand View Estates, is admirably suited for the experiment, because many 'Immortelle' trees have been lost through disease on these and neighbouring estates. The site selected for the trial is a level strip of land having heavy soil combined with liability to flooding. Baker (1) has pointed out that this disease is most abundant where the soil is heavy and rainfall is high. The disease thrives under such moist conditions as occur along the banks of rivers which are liable to flooding. There were very few large shade trees on this site when the experiment began, because of the recent high incidence of 'Immortelle' disease. It was therefore possible to plant the new trees without their suffering from competition with existing shade trees.

The range of species to be included in the trial was determined by the area of suitable land available for planting. Sixteen species were chosen for trial, the majority of these being trees which were previously known to have satisfactory shade-tree habits, but which were mostly unknown as regards suitability for the prevailing conditions on the site of the trial. A few indigenous species, which had not previously been under observation as shade-trees, were nevertheless included in the trial, because they grow under natural conditions resembling those in which 'Immortelle' disease occurs in a plantation.

The botanical names are correctly applied as far as the writer is aware, but because none of the species in this trial has been critically determined, the possibility of wrong identification cannot be entirely excluded.

The original intention was to establish single blocks of fifty plants of each of the trees selected for trial, but in most cases the full complement was not established. It was not possible to achieve complete regularity of planting distanced on account of the presence of drains ans irregularities in the lines of established cacao trees, but a spacing of approximately 30′ by 30′ was the aim. Cacao is generally spaced at 14′ by 14′, but the number of 'Immortelle' trees per acre varies on different estates. A uniform spacing of 24′ by 24′ may be used at the time of planting the shade, but the ultimate spacing of the trees will be determined by the extent to which the stand is reduced, intentionally, and through accidental losses. The ultimate distance apart of the 'Immortelles' is therefore likely to be either 24′, or 48′, or some larger multiple of 24′.

A few of the 'Bocare' and 'Anauca' trees were established from large cuttings, but the majority of them and all the other species included

in the trial were grown from seed. The seeds were germinated in a nursery, except in the case of *Leucaena glauca* Benth., which was established by sowing 'at stake' in the plantation.

Some of the seedlings were grown in bamboo 'pots' and others in wicker 'baskets'. The 'pots' were removed before planting but the other seedlings were placed in the ground without removal of the 'baskets'. The majority of the trees were planted in July, August and September, 1940. Four species as indicated in the Table, were planted in October 1941, and supplies of other species were also planted in that month. There was no further tree planting in subsequent years.

Rainfall and soil-moisture conditions were generally satisfactory at planting times in 1940 and in 1941. There is no reason to suppose, therefore, that the trees established in one of these years were at any initial disadvantage as regards planting conditions, compared with those planted in the other year.

Results

After an interval of about five years from planting, it is possible to draw some preliminary conclusions as to relative suitability of the trees. The information available to date is tabulated below, the dimensions given in the Table are individual tree averages based on measurements of ten specimens, except in the cases of three species of which there were less than ten representatives available, namely *Erythrina Poeppigiana* (Walp.) O. F. Cook [6], *Pterocarpus Rohrii* Vahl [8], and *Crudia glaberrima* (Steud.) Macbr., [4].

In addition to the species listed below, *Symphonia globulifera* L.f., (yellow mangue) was planted in 1941, but failed completely, there were no specimens surviving in 1945.

It will be seen from the Table, that six species have attained greater average heights than the 'Bocare', but that only one species (*Peltophorum ferrugineum*) has a greater average spread at the same age. A feature in favour of *Peltophorum ferrugineum*, which is not brought out in the Table, is the observation that this species was relatively easy to establish in the plantation, consequently a good stand of specimens was obtained and these are relatively even in growth. There is a tendency for *Peltophorum ferrugineum* to produce a dense canopy which may need regulation.

Discussion

The choice of a suitable species, to use as shade for cacao, is determined by several characters of the mature tree. It is not yet possible to provide all the requisite information from this trial of trees, because they are now comparatively young. General information regarding the species referred to above is therefore given, based on published descriptions, amplified by observations made on the trees in this trial. It is hoped that these notes will be of value towards assisting in the selection of trees for planting on estates where conditions are similar to those which pertain on the site of this shade-tree trial.

Acanthaceae

Bravaisia integerrima (Jiggerwood). An evergreen indigenous tree, which may attain a height of 75 feet and a girth up to nine and ten feet. This tree has smooth bark and large leaves, measuring up to ten inches by five inches. The flowers are white with purple and yellow markings, borne in showy panicles. The wood is strong for its weight and easy to work. A mass of stilt roots is formed at the base of the tree.

TABLE

Comparison of species included in trial of trees as shade for cacao

Tree	Average Height (feet)	Average Spread* (feet)	Average Girth† (inches)	Year of Planting
Schizolobium excelsum Vog.	44	9	20	1940
Parkia Roxburghii G. Don	42	16	25	1940
Peltophorum ferrugineum Benth.	30	24	16	1940
Machaerium Tipu Benth.	28	15	11	1941
Sesbania grandiflora Poir	28	14	16	1940
Poinciana regia Boj. [Flamboyant]...	28	13	18	1940
Erythrina glauca Willd. [Bocare]	26	19	20	1940 and 1941
Bravaisia integerrima (Spreng.) Standl. [Jiggerwood] ...	25	11	16	1941
Tabebuia pentaphylla Hemsl. [Pink Poui]	24	16	15	1940
Erythrina Poeppigiana (Walp.) O. F. Cook [Anauca] ...	21	10	12	1940 and 1941
Pithecolobium Saman (Jacq.) Benth. [Saman] ...	20	13	11	1940
Hernandia sonora L. [Toporite]	19	12	10	1940 and 1941
Leucaena glauca Benth.	18	9	7	1940 and 1941
Pterocarpus Rohrii Vahl. [Swamp Bloodwood] ...	18	9	7	1941
Crudia glaberrima (Steud.) Macbr. [Water Locust] ...	8	6	3	1941

* Diameter of individual tree canopy.

† Circumference of tree at approximately 4½ feet.

BIGNONIACEAE

Tabebuia pentaphylla (Pink Poui). A deciduous tree with smooth bark and ornamental rose-coloured flowers. This tree may reach a height of 90 feet in Venezuela where it occurs and is known as 'Apamate'; it has been planted to some extent in Trinidad but is not native here. The timber is not durable in contact with the ground but is useful for inside work.

HERNANDIACEAE

Hernandia sonora (Toporite). An evergreen, indigenous tree, widely distributed in moist forest and occasionally found as large trees in plantations, when the cacao trees appear to do well underneath it. The wood is soft, light and easily worked. The growth of young trees has been noticeably impaired by insect damage affecting the bark and buds.

LEGUMINOSAE

Crudia glaberrima (Water Locust). A large evergreen tree which is native in Trinidad. The wood is moderately hard and heavy. As the growth has been relatively poor, this tree cannot be recommended as a suitable shade tree under the conditions of this experiment.

Erythrina glauca (Bocare Immortelle). A deciduous tree extensively planted as shade for cacao in the lower and wetter areas. The bark is rough and the branches are generally colonized by epiphytes consisting largely of *Bromeliaceae* species. The wood is soft, as also in the case of *E. Poeppigiana*.

Erythrina Poeppigiana (Anauca Immortelle). A deciduous tree, extensively planted as shade for cacao in the higher lands. The flowers are of a brilliant coral colour and the trees are very showy at flowering time. The flowers of 'Bocare' are salmon-coloured and the blossoming trees are much less showy than the 'Anauca' trees.

Leucaena glauca. A small deciduous tree which could only be used as temporary shade for cacao. This tree is easily established by sowing seeds at 'stake' in the plantation, later, the shape of the tree can be readily controlled by pruning.

Machaerium Tipu. A deciduous tree with rather lax branches. The specimens in the trial are not yet sufficiently developed for an opinion to be formed as to the merits of this tree as shade for cacao.

Parkia Roxburghii. A quick-growing tree, ultimately attaining a height of 120 feet or more. The branching is sparse but the large pinnate leaves would seem likely to make this species useful as shade for cacao.

Peltophorum ferrugineum. A quick-growing spreading tree with smooth bark and light reddish-brown, soft wood. This species can be safely recommended as cacao shade, but some pruning will be required to regulate the canopy.

Pithecolobium Saman (Saman). This species has very wide-spreading branches, with a relatively short trunk. It is likely that the huge dimensions of certain specimen trees would not be attained under plantation conditions, where soil is variable.

The saman is bare of leaves for a short period during the year. The bark is moderately rough and the branches generally harbour numerous epiphytes. The wood of young trees is light and soft but in old trees it becomes hard and difficult to work. The wood is durable and dark coloured. It is considered that saman cannot be recommended as a suitable shade tree for cacao. The canopy spread increases so greatly with age that it would be difficult to space the trees in anticipation of the ultimate planting distance required. The surface-rooting habit of the saman might be inconvenient in the plantation and would certainly be intolerable if mechanical cultivation were to be practised in the future.

Poinciana regia (Flamboyant). This tree is quick-growing, with an umbrella shape, which makes it suitable for shade purposes. The flamboyant is bare of leaves for a short period during the year. The bark is slightly rough but this species does not appear to harbour epiphytes. The wood is soft and is not of any economic value. The flamboyant resembles saman in having a surface rooting habit, therefore its use for shading cocoa is also limited on that account. In other respects, the flamboyant seems likely to be a useful shade tree.

Pterocarpus Rohrii (Swamp Bloodwood). This is an evergreen tree with smooth bark and has conspicuous buttresses. The wood is light in weight and is not durable. Although this tree is fairly common in swampy areas, it has not been easy to establish in the shade-tree trial nor have the few established trees made good growth. *Pterocarpus Rohrii* cannot be recommended as a cacao shade tree for planting under conditions similar to those of this experiment.

Schizolobium excelsum. A quick-growing deciduous tree having long 'feathery' leaves; the bark is smooth; the wood is soft and not commercially valuable. Specimens of this species in the shade tree trial have attained heights of over 50 feet within five years from date of planting. *Schizolobium excelsum* occurs in Brazil but there is little information available as to its habit of growth, therefore this tree cannot be recommended as shade for cacao until more experience has been gained as to its suitability for cultivation in Trinidad. Seed germinates slowly and irregularly, therefore it has been found advisable to make an incision in the hard seed coat, with a file, followed by soaking of the seed for 24 hours in water before planting.

Sesbania grandiflora. This is a quick-growing tree, but is said to be short-lived, it is sparsely branched with very light foliage. The wood is

soft and is not durable. The flowers are large and fleshy, they can be cooked and eaten as a vegetable. This species would only be suitable for planting as temporary shade.

Conclusions

The two species (*Schizolobium excelsum* and *Parkia Roxburghii*), which have attained greater average heights than *Peltophorum ferrugineum*, have not yet developed sufficient lateral branches for them to function as good shade trees at about five years from planting. It is likely that the habits of these species will improve in later years, when they may be found suitable as permanent shade-trees on land where the cacao trees attain considerable heights. It seems that where the cacao can become relatively tall, *Peltophorum ferrugineum* may not be desirable as shade, because trees of this species may tend to form lateral branches at too low a level; under such circumstances *Schizolobium excelsum* and *Parkia Roxburghii* may prove useful as substitutes for 'Immortelles'. On the other hand, when circumstances do not demand a particularly high canopy and provided that the necessary attention can be given to the pruning of the trees, *Peltophorum ferrugineum* is recommended as a substitute for Bocare Immortelle.

Specimens were established of three indigenous trees (*Bravaisia integerrima*, *Pterocarpus Rohrii* and *Crudia glaberrima*) inhabiting such wet areas as would seem to be comparable with conditions under which 'Immortelle' disease occurs. It is somewhat surprising that such trees have generally not made satisfactory growth in the plantation, as compared with conventional shade-tree species. *Bravaisia integerrima* (Jiggerwood or White Mangue) has not a good canopy spread but seems otherwise suitable for planting under very wet conditions, if a shade tree is required in such circumstance.

It is not possible to foresee whether any of the trees included in this trial, other than the two species of *Erythrina*, will later be affected by the fungus associated with 'Immortelle' disease. The required information on disease resistance should eventually be available from this trial of trees. It is, therefore, desirable that the plots should be maintained for periodical observations on disease resistance and as regards general suitability for replacing *Erythrina glauca*, in places where that species is affected by 'Immortelle' disease.

Summary

1. An experiment is described where 15 tree species were compared on an area of land where the 'Bocare Immortelle' (*Erythrina glauca*) and to a lesser extent the 'Anauca Immortelle' (*Erythrina Poeppigiana*) are liable to suffer from a fungus disease associated with *Calostilbe striispora*.

2. At an age of nearly five years from planting, none of the trees in this trial has developed symptoms of 'Immortelle' disease.

3. Data are presented on average measurements of height, girth, and canopy spread, for each of the species in the trial.

4. It is found that *Peltophorum ferrugineum* is worthy of further trial as a shade tree substitute for Bocare Immortelle, when a moderately high canopy is required.

5. Where a high shade canopy is desired, *Schizolobium excelsum* and *Parkia Roxburghii* appear likely to meet the requirements.

6. The trial was carried out in a wet area where the land is liable to flooding. It was observed that Jiggerwood (*Bravaisia integerrima*) made satisfactory growth and could serve as a cacao shade tree, if required for conditions where the land tends to be waterlogged.

7. Descriptive notes are given for the 15 species included in this trial of trees.

Acknowledgments

This experiment was made possible through the generous co-operation of Mr. Alfred Mendes, who kindly provided the necessary land and facilities at Sta. Carlotta and Grand View Estates.

Grateful acknowledgment is made to Mr. R. L. Brooks, Conservator of Forests, for assistance at the start of the experiment, and for later advice. I also wish to thank Mr. J. C. Muir, Director of Agriculture, for his suggestions adopted in the preparation of this paper. I am indebted to Professor E. E. Cheesman, Imperial College of Tropical Agriculture, for information regarding the botanical nomenclature.

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NEW USES FOR GROUNDNUTS

The United States Department of Agriculture is finding new and more efficient uses for groundnuts in addition to their already big-business role as producers of a high-grade vegetable oil. The high-protein meal left after oil extraction has long been used as livestock seed; but now industry comes forward to compete with livestock for a share of it. Peanut protein has been found useful in adhesives, paper sizings and fabric coatings, by chemists at the Southern Regional Research Laboratory in New Orleans. The sugary liquor remaining after protein extraction can be used as a culture medium for a food yeast, thereby providing an additional source of protein for livestock feeding. At the Northern Regional Research Laboratory in Peoria, Ill., chemists have developed a method for using ground-up peanut hulls instead of ground cork as a basis for crown cap liners for bottles.—(*Science*, Vol. 102, No. 2636.)

DIAGNOSIS OF MINERAL DEFICIENCIES IN CROP PLANT*

BY

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Liebig, in enunciating his mineral theory of the nutrition of crops in 1840, advanced the view that simple plant analysis would suffice to provide the data to determine the mineral requirements of crop plants and the amounts of mineral nutrients necessary to add to the soil to make good shortages due to removals by crops.

The field experiments of Lawes and Gilbert soon showed this conception to be erroneous and resulted in attention being focused on field trials and soil analysis as means of solving problems of crop nutrition, including deficiencies of mineral elements. From that time until 1920, these remained practically the only two methods in general use for determining deficiencies of mineral nutrients and the fertilizer needs of crops, and they still continue to play important parts in the solution of these problems.

Since 1920, however, other methods for diagnosing the mineral status of crop plants have been developed, based primarily on the plants themselves. In attacking problems in the field these methods are given complementary rôles, and field trials and soil analysis are also included, with the result that problems are attacked from many angles and a choice of methods is available to suit the varied conditions which occur.

The new methods include visual diagnosis, foliage, spraying, injection of leaves and stems, and chemical analysis of leaf laminae and petioles and of stems.

In practice it has been found that none of the methods used alone will provide a complete solution of deficiency problems in all circumstances, but when used in complementary rôles and with varied emphasis to suit different conditions, they have proved effective in solving very diverse and difficult problems.

Visual Symptoms of Mineral Deficiencies †

The visual symptoms which result from mineral deficiencies in crop plants have proved a valuable aid in diagnosis and form the basis of the visual method discussed later. In view of the importance of this method to technical agriculturists, it was considered worth while to devote one lecture entirely to the subject of deficiency symptoms.

Although the symptoms produced are very varied they allow of some classification and grouping. Thus deficiencies of nitrogen, phosphorus, potassium and magnesium always affect older tissues first, and the visual signs progress systematically from the older to the younger parts of the plants, whereas the deficiency effects of calcium, iron and boron invariably appear first in meristematic tissues and often result in the death of growing points.

In field crops in Great Britain, deficiencies of all the essential elements, with the exception of sulphur, copper, zinc and molybdenum, have been recorded and frequently occur, and it is thus of interest to summarize some of the main features of the deficiency effects which have been observed.

The effects produced by nitrogen deficiency are very consistent over a wide range of plants. Growth is greatly reduced, stems are upright and thin, and lateral shoots are few, leaves are small and usually pale green in colour, flowering and fruiting are much reduced, and autumn tints of leaves, stems and fruits are usually brilliant, consisting of yellow, orange, red and purple colours. Defoliation is premature.

Phosphorus deficiency produces many effects similar to those resulting from nitrogen deficiency, but leaf symptoms are more variable. They may take the form of high colorations as for nitrogen deficiency; but more often the tints are dull shades of purple, or tints may be absent altogether, the leaves remaining a dull, lustreless, olive green, or the margins may become 'scorched'.

Potassium-deficient plants are generally squat in habit because of short stem internodes and, unlike deficiencies of nitrogen and phosphorus, lateral shoots may be abundant while shoots may die back. Marginal leaf scorch is a very common symptom, but leaves may also show tip scorch, chlorosis, spotting and backward or forward curling of the laminae. Bright tints are often lacking, though not invariably so.

Calcium deficiency results in the death of the growing points of shoots, which condition may lead to the development of adventitious laterals, and in the distortion, wilting and scorching of leaf margins, collapse of petioles and the death of flowers. Root growth is much restricted and tuber formation seriously affected.

Magnesium deficiency is remarkable for the diversity of leaf effects produced. These include chlorosis, brilliant tinting with well-defined colour patterns, intervenal necrosis (both central and marginal) and spotting. The effects produced are often highly spectacular and ornamental. Defoliation is generally serious and may follow very quickly after the appearance of leaf symptoms. Deficiency effects usually develop at a relatively late stage of growth.

Iron deficiency is characterized by chlorosis of the foliage, which develops first on the young leaves at the tips of shoots and later spreads to the older foliage. As the veins often remain green the chlorotic pattern may take several forms, such as mottling or striping, according to the venation of the leaf.

* Summary of two lectures delivered at the Royal Institution published in *Nature*, Vol. 155, No. 3937, pp. 444-46, 1945.

† For a full account and for illustrations of visual symptoms, *see* "The Diagnosis of Mineral Deficiencies in Plants by Visual Symptoms" (with 1944 Supplement) by T. Wallace. (H.M. Stationery Office) 15*s*.

The effects of manganese deficiency vary considerably. Many plants show leaf chlorosis similar to iron deficiency; but others, like oats and peas, develop symptoms unlike those produced by any other deficiency. Thus oats show lesions of the leaf tissues—grey speck—and peas lesions in the flat surfaces of the cotyledons—marsh spot.

Boron deficiency effects are notable both for their diversity and severity. They result from abnormalities in the development of meristematic tissues. The effects for individual crops are often so striking that many have been given descriptive names by growers, for example, heart rot of sugar beet, brown curd and hollow stem of cauliflower, cracked stem of celery and brown heart of swede. The injuries produced may affect growing points, epidermis vascular tissues or pith.

Visual Diagnosis

In its simplest form, visual diagnosis consists of a comparison of plants growing under conditions of mineral deficiencies with suitable standards of deficient plants, usually in the form of photographic records and detailed descriptions. In practice, wherever possible, use is made of 'indicator' plants These are plants which show characteristic effects for particular deficiencies and on which the deficiency symptoms are readily recognized. Examples of such plants are oats as an indicator plant for manganese deficiency, sugar beet for boron and potato for potassium.

Where indicator plants are present in instances of deficiencies in the field, particular deficiencies can usually be identified by mere inspection of the visual symptoms, but where this is not possible other methods must be used either wholly or in a confirmatory rôle.

Where the cropping potentiality of land is unknown as has frequently occurred in the breaking up of new areas for arable cropping during the War, the visual method may be employed on special indicator plots. These plots combine indicator plants as crops sown in strips, crossed with a number of manurial dressings which arrangement results in all the crops growing under conditions of the presence and absence of each of the particular elements likely to be deficient. This scheme has proved effective in solving a number of difficult problems.

The visual method cannot be applied in instances where symptoms are masked or prevented from developing by attacks of certain pests and fungus diseases and by certain other factors.

In applying the method, it is often useful to make observations on certain soil characters, for example, pH, texture and drainage, and in all doubtful diagnoses confirmation must be sought in the complementary methods.

Foliage Spraying and Plant Injection

These two methods both aim at introducing mineral nutrients into plants through stems and leaves, and they may be used as alternative procedures according to convenience of application.

Plants under experimental conditions may be supplied with their entire requirements of mineral nutrients, either major or trace elements, by means of foliage sprays, and in practice spraying is often more effective than soil applications for supplying trace elements, particularly for manganese and iron, which often cannot be given through the soil where deficiencies of these occur. Spraying methods are very simple. It is only necessary to know the correct strength of spray to use and the best time to spray. A watering can fitted with a rose is suitable for use on all ground crops, while for trees a pressure sprayer is required.

In practice, for trace elements the solutions used contain 1-2 oz. trace element compound per 5 gallon applied to 30 sq. yd. and for trees 3 lb. per 100 gallon is a suitable concentration; major elements are usually only applied to ground crops, at strengths of 1-2 lb. per 5 gallon. Where the foliage is difficult to wet it may be necessary to add a wetting agent.

Spraying is especially valuable for use with the visual method. Results are generally evident 5-10 days after treatment.

Both solids and solutions are used for injections, the former being useful only where woody stems are available for treatment. Solid injections are especially valuable for iron deficiency, as applications of iron salts to the soil are usually ineffective and sprays often damage the foliage. The technique of solid injections is based on the method originally evolved by Bennett (1).

Roach, at East Malling, has been responsible for the methods of liquid injection in use. The injections are made on laminae and petioles of leaves and on stems, and methods have been developed for use on plants as widely different as cereals and trees (2). The periods required for responses from liquid injections are similar to those for sprays.

With injection methods the time and dosage factors are again important.

Chemical Methods

In applying methods of chemical analysis to plants as a diagnostic procedure due regard is paid to established principles of plant physiology. The plant parts used comprise leaf laminae, petioles and stems, as representing parts of the plants which reflect most accurately their mineral status. It is usual either to compare the status of mineral nutrients of healthy and unhealthy plants growing in close proximity or to make comparisons with standards fixed from previous experience. In this latter connexion it has been found possible, when sampling methods are standardized, to fix 'threshold' values for the various elements in particular plants below which deficiencies may be expected. The chemical data are generally computed on a basis of dry matter.

In selecting material for analysis, samples must be comparable from the physiological point of view, otherwise growth and seasonal cycles may render comparisons invalid.

During recent years, methods for carrying out rapid chemical tests on plant tissues, suitable for use either in the field or laboratory, have been

introduced (3), which have proved useful in indicating deficiencies and in confirming the results of other methods.

The development of spectrographic and polarographic methods has also speeded up routine analytical procedures and made possible the detection of unusual elements giving rise to new problems.

A special technique for chemical diagnosis has been developed by Lagatu and Maume (4) in France and by Thomas and Mack (5) in the United States, which has been designated 'foliar diagnosis'. The method compares the nutrient status of test plants with that of healthy, heavy-cropping plants, regard being paid to seasonal cycles of nutrients and to quantitative and qualitative aspects. The method is, of necessity, somewhat slow for general advisory purposes.

Chemical methods, however, are not infallible and if used alone may fail to provide the correct solution to certain problems. This is particularly so in instances of iron deficiency, where the element apparently becomes immobilized within the plant tissues from a variety of causes, as in lime-induced chlorosis, some instances of potassium deficiency and in the presence of toxic concentrations of other elements.

Soil Analysis and Field Trials

During the course of long useage, these methods have undergone considerable elaboration, soil analysis chiefly by the development of methods of determining 'available' nutrients (6) and by the introduction of rapid methods (7), and field trials by the development of designs allowing of statistical analysis (8).

The data provided by soil analyses can be of great value when used by an expert and supported by previous field experience, but they must be regarded only as pointers to probable mineral deficiencies since the intake of minerals by plants is not determined solely by chemical supplies in the soil. The method is chiefly of use for phosphorus and potassium deficiencies, and in providing data relating to acidity and organic matter.

As the response of the crop to a nutrient element, however the response may be obtained, must always be regarded as a final test of a deficiency of a particular element, field trials must always be of importance in diagnosis. But even here erroneous conclusions may be drawn, particularly so where trace element deficiencies may be remedied by changes in the pH of the soil. Thus, applications of sulphur to the soil may remedy a deficiency of manganese and alleviate deficiencies of iron and boron by lowering the pH, and conversely the application of lime may cure a deficiency of molybdenum. Moreover, soil dressings of manganese and iron salts are ineffective in many soils against these deficiencies, which nevertheless may be quickly and completely remedied by spraying or injection treatments.

The usual field trial methods may also be too slow in producing results for advisory purposes, as for example, for deficiencies of potassium and magnesium of fruit trees.

Experience with mineral deficiencies of crops in the field has shown that the problems may be very complicated and that no one method can be relied upon to provide a general solution. The most effective procedure is to use all available methods of attack in a complementary way, and in doing so, full use should be made of all the data which the plants themselves provide.

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INFLUENCE OF MICROORGANISMS AND SOME ORGANIC SUBSTANCES ON SOIL STRUCTURE

Many organic substances, dextrose, sucrose, starch, peptone, cellulose, and gum arabic, did not contribute to soil-structure stability, though these substances do furnish energy material for soil microorganisms, which can convert them readily into either microbial tissue or decomposition products that increase soil-structure stability. Lignin, proteins, oils, fats, waxes, resin, and paraffin increased the stability of lumps of Peorian loess to water drops. Inorganic salts did not increase the stability. Of several wetting agents added to Peorian loess, one increased stability, whereas the others had no effect. They decreased the stability of Marshall topsoil. Some of the strongly adsorbed organic substances such as the basic dyes increased slightly the stability of the Peorian loess.

Increased structure stability resulting from biological activity is temporary, apparently remaining as long as the stabilizing decomposition products exist.

Quantity of organic matter does not seem so important as quality in producing stability to water drops. It would appear from these results that any substance decreasing the rate of wetting or the swelling of the soil would increase its structure stability to water drops.—(Abstracted from *Soil Science* Vol. 59, No. 4, p. 287, 1945.)

AGRICULTURE IN THE MATENGO HIGHLANDS *

BY

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(NOTE.—*This article is of particular interest in that it describes a system of cultivation which has been recommended for adoption on some of the steepest land situated in the Leeward and Windward Islands.—Ed.*)

IN travelling from Songea towards Lake Nyasa, one passes through the Matengo country, a small highland area which is a continuation of the Livingstone Mountains. It is a pleasant land of bubbling streams, varying in altitude between 4,000 and 7,000 feet. The hills are steep and the valleys narrow. There are no trees, except for small patches of surviving rainforest on the higher mountains. The traveller cannot help noticing that even the steepest hill slopes are cultivated. These hillside cultivations are of very striking appearance, showing an orderly lay-out, with straight-cut edges, and the surface of the fields is curiously pitted. The impression gathers force that this cannot be native cultivation. But it is. What is the tribe who practise this peculiar system? Under what circumstances did the system evolve? What are its objects?

The Wamatengo are a small tribe inhabiting the highlands between the Ungoni Plateau and Lake Nyasa in the Songea District. At one time they occupied broader lands, but the arrival of the raiding Wangoni (of Zulu-Swazi origin) and the slave raiders drove them into the mountains where they now reside.

Constant raiding by the Wangoni drove them further and further into the hills, and restricted their settlements to the neighbourhood of large natural caves which could be defended, or to the most inaccessible mountain tops.

The problem of survival in such steep country, and in such restricted areas must have been acute; but the Wamatengo proved equal to it. Not only did they evolve a system which gave them a degree of immunity from the most destructive raids, but they also evolved a system of agriculture, including crop rotation, systematic fallowing, and soil conservation measures, which enabled them to keep their restricted lands under constant cultivation, and to preserve their precious soil against erosion even on the steepest hillsides.

The Wangoni raided the Matengo country for foodstuffs and women. (There were no cattle.) The women were protected in the caves and on the less accessible mountain tops. They were often made unattractive by mutilation. Foodstuffs were made readily available to the raiders in the most accessible and fertile valley-bottoms. So long as these valley-bottom supplies lasted, the less accessible hillside cultivations were left alone. Thus the Matengo peasant cultivated about twice as much land as needed. Half of his crop he expected to lose to the raiders, and the other half he hoped to retain for his own use. To this day he cultivates in the most energetic manner about twice as much land as he needs, and disposes of the surplus. This paying of a food tribute to the Wangoni may have been imposed on the Wamatengo. On the other hand it may have been evolved by the Wamatengo for their own protection.

The drain upon the scanty soil resources available to the Wamatengo must have been severe. They had to feed themselves and at the same time supply a satisfactory amount of food for the raiders. The problems of how to maintain fertility, and how to prevent erosion on the steeply sloping land available had to be tackled. The system evolved to meet these problems is probably unique, and will be best understood if a description is given of how the work is undertaken.

When breaking land from grassland or fallow, the Wamatengo men cut the grass and lay it in rows forming a grid. One set of rows roughly follows the contour, and the other set is at right-angles to the first set. The rows are seven to ten feet apart, depending on the amount of grass to be covered, and on the depth of fertile soil with which to cover it. When this work is viewed from a distance the crossing rows of grass with the squares of soil in between give a "chessboard" effect. Cultivation is done by the women. (The men used to stand guard.) Each village works communally with accompanying beer drinks, but each field is individually owned. The soil in the squares is dug out and pulled on top of the rows of grass. The cultivator works round each square in turn. Thus one quarter of the work has to be done while facing down-hill and dragging the soil upwards. Half of the work is done while standing sideways to the hill. This prevents denudation of hill tops. Digging continues until the subsoil is exposed in the centre of each square. When this work has been completed, the surface of the field is pitted where the squares had been, with beds of soil between the pits underlaid by a layer of grass compost. The pits are four to five feet across and so are the soil beds. Up to a square yard of subsoil is exposed in the bottom of each pit. Storm drains are not made if a hillside is cultivated by this method right up to the top, but where the hilltop cannot be cultivated, a storm drain is usually made above the highest cultivated field.

The women do the planting on the raised soil beds surrounding the pits. Maize is planted in short lines which tend to be radial from the pits. The lines are about one yard apart and with single

* Reproduced from *East African Agricultural Journal*, Vol. X, pp. 22-24.

seeds spaced at about one foot in the lines. The maize is nearly always planted as a pure crop. On a second field similarly cultivated, beans and peas are planted as pure crops at a spacing of four to six inches in each direction. This gives a very dense stand of these crops.

Clean weeding is the rule. Weeds are pulled out and thrown into the pits where they form a valuable compost with accumulating silt. At the end of the season, crop residues are also deposited in the pits, the old soil beds are split and the new beds formed over the old pits. The new pits occupy the place where the old beds intersected.

The rotation adopted is the simple one of alternating a grain crop (maize) with a leguminous crop (beans and peas). This alternation is absolutely regular and is carried on until the soil requires to be fallowed. The fallowed fields simply revert to natural grasses. The pits of the old cultivations remain and continue to function as an effective check to erosion on the fallowed land. The fallowing is systematic but not regular, because it depends on the relative fertility of the other fields at the disposal of the cultivator. Careful cultivators keep their land under cultivation for eight to ten years before fallowing is necessary.

The rotation of crops, the fallowing, and the returning of all weeds and crop residues to the soil form good agricultural practice which calls for no special comment. The pit system of cultivation (really a system of "box ridging") is so effective as a check to erosion that its functioning will bear examination. The technique is simple and almost fool-proof. No instruments are required; only a billhook with which to cut the grass, and an ordinary hoe with which to do the digging. Hillsides, so steep that it is impossible to ascend without using one's hands, are under cultivation and there is no erosion. No dangerous accumulation of water is possible, as any overflow from one pit is trapped by the next. Even heavy downpours are fully trapped and the water gradually sinks into the subsoil, so that even the smaller streams starting high on the hills do not dry up in the dry season. Footpaths and roads do not suffer from washaways, and—greatest benefit of all—shifting cultivation is unknown to the older generation of Wamatengo. Fertility has been retained and built up. The exposure of the subsoil, and the accumulation of humus is gradually deepening the layer of fertile soil, and so the Wamatengo evolved a system of agriculture adapted to their particular circumstances. The tribe survived, so the system must have been effective. Is the Matengo pit system of cultivation the answer to some of the ills of erosion from which Africa suffers? There seems little doubt that it could be of wide and beneficial application, whether on steep hillsides or on gentle slopes. Some crops do not grow well on the beds of soil with the grass or compost below them. Examples are cassava and groundnuts; but with due caution in adapting the system to any local needs, it should prove beneficial almost everywhere.

The technique outlined above seems to be of recent origin. On some of the Matengo hill slopes, large tree roots testify to the existence of extensive forests in the not too distant past. Such hill slopes are badly eroded and bear no trace of the pit cultivations. Did the Wamatengo cultivate these slopes? The first defensive position occupied by the tribe is near the caves at Langiro, and the surrounding country there is badly eroded, even although it is now cultivated by the pit system. The second defensive position occupied is at Litembo, where every available scrap of land has been under cultivation by the pit system for a considerable period (certainly sixty years), and there are no signs of deterioration. These facts tend to show that the system was evolved in recent times, and that the dominating cause was lack of land for cultivation. Now that there is no shortage of land, the younger generation of Wamatengo are moving outwards from the old settlements and adopting lazier methods of cultivation. They are losing their grip on a valuable heritage. The introduction of cash crops is accelerating this deplorable breakdown, because they are exclusively the affair of the men. The women stick to the old system of producing the traditional food crops.

To end these notes, it may be as well to recall parallel cases, where pressure of circumstances forced the evolution of special types of agriculture. The natives of Ukara Island, in Lake Victoria, evolved their system of mixed farming, stall feeding of cattle, and the use of manure and compost on their fields, in order to meet the pressure of population on a section of land which could not be extended and which had to be kept under cultivation. There must be other cases of this kind. Must there be severe pressure of circumstances, *e.g.*, of population, of land, of economics, &c., before such desirable systems can evolve? The success or failure of many peasant settlement schemes will depend on the answer to that question.

Rotation

(1) Virgin or fallow land prepared in the dry season, or residues of beans and peas dug in during September or October in preparation for planting maize with the first rains in November-December.

(2) Maize residues of previous crop cut and thrown into the old pits. Sometimes burned and then buried in February-March. Beans and peas planted in March-April.

(3) In the second year the maize crop follows on the land which carried the previous pulse crop, and the pulse crop where the maize had been.

DEATH OF MR. DE LISLE H. A. CORBIN

As we go to press we learn with deep regret of the death on 7th November, in the Knickerbocker Hospital, New York, of Mr. De Lisle H. A. Corbin, who was for many years Manager of the Milner Hostel. An Obituary Notice will appear in our next issue.

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

Role of Calcium in Ground-nut Production

In an article entitled "The effect of calcium on yield and quality of large-seeded type peanuts", which was published in Vol. No. 6, 1945, of the *Journal of the American Society of Agronomy*, Messrs. W. E. Colwell and N. C. Brady, adduce experimental evidence to prove that the development of full ground-nut fruits, devoid of ovarian cavities, is largely dependent on a suitable supply of calcium in the soils.

They write:—"Although the use of certain calcic materials has been known to be beneficial in the formation of well-developed kernels, their addition to soils of the peanut area of the south-eastern states has not produced favourable results in many of the reported experiments. Furthermore, the effects reported from the use of lime-stone and gypsum as sources of calcium are quite different. Those working with the problem are continually confronted with certain inconsistencies in results that have been inadequately explained.

The purpose of the present study was to investigate certain factors which affect the response obtained from large-seeded varieties of peanuts to calcium additions. Varietal differences with respect to calcium nutrition are to be reported in a subsequent paper. Results are reported from field experiments in which particular attention was given to (*a*) comparisons of two different practices used to supply calcium, (*b*) the placement of gypsum, and (*c*) chemical characteristics of the soils on which the experiments were used to evaluate the behaviour of the peanut plant to calcium variables.

Results of the investigation show that calcium is an element of major importance in the nutrition of large-seeded type peanuts, and, although a very low level of soil calcium is adequate for vegetative growth, a relatively large supply is necessary for proper development of fruit. From the standpoint of practical production, the results of this study reveal that an adequate soil fertility program for peanuts should be one in which attention is directed toward raising the calcium content of the soil to a level adequate for the development of peanut fruit, provided this level is not unsatisfactory for other crops in the rotation. If it is impractical to raise the calcium level of the soil to this point, localized applications of a relatively soluble calcium salt, such as gypsum, may be made with advantage".

* * *

Leaf Analysis in Estimating the Potassium, Magnesium, and Nitrogen Needs of Fruit Trees

During the last few years there has been increasing interest in the value of tissue analyses for the diagnosis of nutritional deficiencies of fruit trees, as well as of other plants. In New York, leaf analyses have been found helpful in furnishing measures of the needs of fruit trees for potassium, magnesium, and nitrogen fertilization. It is the purpose of this paper to bring together data that indicate the usefulness and some of the limitations of such analyses.

Summary: Leaf analyses for total potassium, magnesium, and nitrogen, expressed on the dry-weight basis, were found under some conditions to indicate the needs of fruit trees for these nutrients. The composition of fruit tree leaves with respect to those three elements was also found to be influenced by the condition of the root system and conducting tissues of the tree, injuries to the leaves from toxic sprays or fertilizers, the age of the leaves, the climate, the season, ionic interrelationships, and the kind and variety of fruit tree. Data are presented to indicate the possible significance of these factors. It is concluded that chemical analysis of leaves for these constituents cannot take the place of careful observations on tree behaviour and appearance, on the development of visible leaf or fruit symptoms, and on past climatic and management conditions; but that chemical analyses of leaves, coupled with these observations, may make possible a positive diagnosis that neither alone would have permitted.—(Abstracted from *Soil Science*, Vol. 59, No. 5, pp. 339-349, 1945.)

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The Nutritive Value of Proteins and Non-protein Nitrogen for Ruminants

Dr. J. A. B. Smith in his paper explained that it was now realised that rumination is a much more involved process than simple maceration of the food and digestion of the cellulose. For example, at least one vitamin is probably destroyed in the rumen while others are synthesized, and there is little doubt that the nitrogenous constituents of the diet are materially changed in the rumen. The relative nutritive value of proteins in the feeding of ruminants is exceedingly difficult to determine. For growth there is probably little difference in the net utilization of protein from various sources, although in milk production the quality of the protein may be much more important.—(*Chemistry and Industry*, No. 15, p. 117, 1945.)

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